

Energy & Climate

Vision

To enhance the nation's security and prosperity through sustainable, transformative approaches to our most challenging energy and climate problems.

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Reducing Soft Costs of Rooftop Solar Installations Attributed to Structural Considerations

Barriers to greater penetration of distributed renewable generation, such as residential rooftop photovoltaic (PV) arrays, include issues unrelated to PV efficiency or unit cost. Sandia is working to mitigate these "soft cost" barriers to increase market penetration to the maximum extent possible.

An identified market barrier to rooftop solar photovoltaic (PV) installations involves structural obstacles in adhering to applicable building codes in the construction permitting process.

Until recently, the PV industry has largely ignored structural aspects related to solar installations. However, it was recognized during the Solar America Cities program that a primary market barrier to new solar installations is the difficulty and cost involved in obtaining construction building permits for rooftop solar installations related to structural issues.

This market barrier stems from

- Conservatism in existing engineering methodologies for evaluating roof structures
- 'Perceived' inadequate loadbearing capacity of some existing roof structures
- Lack of understanding of how to economically strengthen structurally inadequate roof structures
- Conservatism in the current national structural codes, particularly ASCE7-10 and IBC
- Difficulty in understanding and interpreting current structural building codes
- Time and cost of involving a structural engineer in the permit application
- Inability of today's solar professionals to address structural concerns in the building permit application.





A simulated roof system with an air bladder applying a uniform load below it (pushing up) was used to test the assembled rafters to failure. Structural failure coincides with the most visually obvious grain inclusions.

A Barrier of Perception More Than Fact

It is estimated that ~80% of existing residential roof structures do not meet the structural loading requirements described in ASCE 7-10. That is, the perceived load-carrying capacities of these homes are inadequate before applying new loads from such things as a solar system. However, our research shows that the conservatism in the code and more so the analysis methodology engineers use significantly underestimates these roof structures' actual load-carrying capacity.

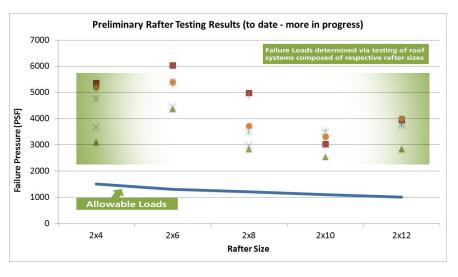
Customary engineering analysis methods assume that rafters, joists, and trusses act alone to carry rooftop loads. This is an oversimplification. In fact, a roof framing system is a very indeterminate structure. Roof analysis is further complicated because the primary building material is typically wood, which has a wide variety of structural properties depending on its classification, species, condition,

use, size, moisture content, and so on. Thus, engineers tend to be very conservative in their analyses.

Roof Structures Are Much Stronger Than Believed

Based upon input received from engineers, solar installers, and building-code officials, over 80% of existing residential rooftops only appear to not meet the most common current structural code (e.g., ASCE 7-10, IBC 2009) requirements—before PV panels are installed. That is, the lack of loadcarrying capacity for many houses is a perceived issue rather than a 'real' one. Why? Because current engineering methodology considers only the rafter to withstand applied loads rather than the roof structure as a system.

A recent Master's thesis [Campos et al. 2012] describing small-scale testing at the University of New Mexico (UNM) reveals that a single wood joist is significantly strengthened by the composite action of oriented strand board (OSB) roof sheathing nailed to the joist using typical construction practice. These preliminary results show that by simply considering the nailed sheathing acting compositely with the underlying joist may increase the joist's statistical mean



Data from a series of tests on each of five rafter sizes show actual failure loads compared to the code-determined allowable loads.



A roof structure is made stronger by the system elements working together—much stronger than its main load-bearing element, the rafter, is alone. Current engineering analysis methods do not take this "composite action" into account when evaluating its strength.

strength by ~35%. Furthermore, also gluing the sheathing to the underlying rafter may increase the mean beam strength by as much as 74%. Thus, including the sheathing's contribution (which is not included in typical analysis) may increase a single rafter's strength by as much as 74%. In addition, the load-sharing and load redistribution that takes place in a roof system can significantly add to the roof's actual strength.

Reducing Soft Costs of Rooftop Solar Installations Project

Through an extensive test program, Sandia engineers are developing the data that will expose the conservatism in applicable building and structural codes and more so that the analysis methodology used by engineers significantly underestimates a residential roof

structure's actual load-carrying capacity.

Expanding on the original laboratory program, testing has begun to assess the actual load-carrying capacity of residential rooftop structures. These empirical results are then compared to perceived load-carrying capacity of the similar structures calculated based on applicable codes.

This project will:

- generate defensible empirical data to enable permitting of many current applications that are disallowed due to perceived inadequate strength of the existing roof structure,
- demonstrate standardized rooftop installations to ease permit costs,
- produce a quality certified report summarizing testing activities performed with associated results comparing the actual loadcarrying capacity of a variety of residential rooftop structures with values computed following applicable regulations, and
- produce a guidance document summarizing recommended design installations and retrofit options should they be required.